Mid-IR Optoelectronics: Materials and Devices
Room Lecture Hall, Nielsen Hall - Session MIOMD-WeM1

Plenary Lecture & Applications of Mid-Infrared
Moderator: Rui Yang, University of Oklahoma

8:30am **MIOMD-WeM1-2 Plenary Lecture: Coherent Control of Quantum Cascade Laser Frequency Combs via Optical- and RF-Injection***, **Gerard Wysocki**,* Princeton University **INVITED**

Quantum cascade laser (QCL) frequency combs are compact, all-electrically driven, broadband semiconductor laser sources operating in the mid-infrared spectral region that give access to fundamental vibrational bands of many molecular species of environmental and industrial importance. These lasers are being extensively used to perform dual-comb spectroscopy (DCS) and sensitive molecular sensing with high temporal resolution. However, unlike the metrological-grade frequency combs based on mode-locked lasers, freerunning QCL-combs are susceptible to intrinsic phase and intensity noise, which makes applications to high-resolution spectroscopy relatively difficult. In this talk I will discuss techniques utilizing external cavity optical feedback injection as well radio-frequency (RF) electrical signal injection to achieve improved comb coherence for dual-com spectroscopy, as well as generate higher-order harmonic QCL comb-states with improved coherence and broader optical bandwidth. Experimental results demonstrating independent control of primary comb parameters (offset frequency , f0, and repetition rate frequency, frep) via opticaland RF-injection, resulting in MHz-level frequency control and gapless DCS tuning, will be discussed in details.

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9:10am **MIOMD-WeM1-6 Compact QCL-Based Coherent Lidar in the Mid-Infrared***, **Bruno Martin**,* Thales / Laboratoire de physique de l'Ecole normale supérieure, France*; P. Feneyrou,* Thales research and technology, France*; N. Berthou,* Thales SIX, France*; D. Gacemi,* Laboratoire de physique de l'Ecole normale supérieure, France*; A. Martin,* Thales Research and Technology, France*; C. Sirtori,* Laboratoire de physique de l'Ecole normale supérieure, France **INVITED**

Frequency-modulated continuous-wave light detection and ranging (FMCW LiDAR) is a technique for fast and precise measurements of distances and speeds of hard and diffuse targets. Moreover, the effects of feedback reinjection on the laser parameters, such as the optical power, wavelength or voltage can be utilized for numerous sensing applications. We show the first experimental demonstration of a FMCW LiDAR in the mid-infrared, based on a novel self-mixing interferometry technique and compare it with a conventional mid-infrared FMCW system. Thanks to an injection current predistortion technique, high-speed and precise linear optical frequency modulation (LFM) up to 8 GHz in 1µs with less than 1% error to linearity is achieved, allowing a greater FMCW signal-to-noise ratio.

One part of the beam (> 90%) is sent to a target in order to perform distance & speed measurement. In the absence of optical isolation, a part of the reflected light will come back inside the laser cavity, interfering with the intracavity field. The changes induced simultaneously on the optical power and frequency are monitored on a photodiode at the output of the interferometer. More specifically, the measurement of the periodic perturbation on the LFM allows for speed and distance measurement, without adding any new components to the LFM system. Taking advantages of intrinsic high-speed dynamics of mid-infrared unipolar sources and detectors, we achieved kHz-rate sub-cm precision measurement of low-reflective targets at distances up to 25 m. Such results pave the way to systems more robust against meteorological perturbations and with an improved discreetness. Moreover, the overall compactness and robustness of the optical setup constitute a leap toward the development of mid-infrared quantum optoelectronic devices and their integration into components.

9:40am **MIOMD-WeM1-9 A Markov Chain Approach for Modeling Polarized Infrared Radiative Transfer in Optically Anisotropic Media***, **Feng Xu**,* University of Oklahoma*; W. Espinosa,* NASA Goddard Space Flight Center*; O. Kalashnikova, A. Davis, D. Diner, M. Garay,* Jet Propulsion Laboratory (NASA/JPL)*; J. Gong,* NASA Goddard Space Flight Center*; B. Chen, L. Gao, J. Redemann,* University of Oklahoma*; Z. Zeng,* California Institute of Technology, China

The polarization state of atmospheric radiation contains abundant information about aerosol and cloud particle properties. To assist in the combined use of reflected and emitted radiation for dust and cloud remote sensing, we developed a Markov chain approach to model polarized infrared radiative transfer in an optically isotropic or anisotropic medium (e.g. Earth atmosphere). A multi-steam scheme is adopted to resolve the angular dependence of total radiance and polarized radiance. Our model accounts for atmospheric emission, scattering, and absorption, as well as directional surface emission and reflection. Non-spherical particles with random and preferred orientations are considered. Simulation is performed for three reference Earth atmospheres (mid-latitude summer, sub-arctic winter, and tropical) which contains dust particles, water droplets, and ice particles of preferred or random orientations. These reference atmospheres overly an ocean or a land surface which contributes both surface emission and reflection. The numerical simulation shows a) remarkable impact of particle orientations, non-sphericities, and the linear and circular polarization components of infrared extinction matrix on the infrared polarimetric signals. By contrast, the infrared radiances are much less impacted.

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